



LONDON- WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA10 | Dunsmore, Wendover and Halton

Water resources assessment (WR-002-010)

Water resources

November 2013

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise three parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area are also provided. For the Dunsmore, Wendover and Halton area (CFA10) these are:

- a water resources assessment (this appendix); and
- a flood risk assessment (Volume 5: Appendix WR-003-010).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water resources and flood risk assessment Map Book.

1.2 Study area

1.2.1 The study area for CFA10 is mostly rural with agricultural land and woodland. This area is also partly within the Chilterns Area of Outstanding Natural Beauty (AONB). The route comprises the Wendover Dean viaduct and associated embankments where the scheme enters this study area from the south-east, before entering the Rocky Lane South cutting and the Small Dean viaduct and embankments to the south-east of Wendover. To the north and north-west of Wendover the scheme comprises the Wendover green tunnel and Wendover north cutting.

1.2.2 The spatial scope of the assessment was based upon the identification of surface water and groundwater features within 1km of the centre line of the route, except where there is clearly no hydraulic connectivity. For surface water features in urban areas, the extent was reduced to 500m. Outside of these distances it is unlikely that direct impacts upon the water environment will be attributable to the Proposed Scheme. Where works extend more than 200m from the centre line, for example at stations and depots, professional judgement has been used in selecting the appropriate limit to the extension in spatial scope required. For the purposes of this assessment this spatial scope is defined as the study area.

1.2.3 The main environmental features of relevance to water resources include:

- the dry valley of the upper River Misbourne and dry valleys of the Chalk scarp at Wendover;
- the Wendover Brook and its tributary watercourses including the drain at Church Lane and Castle Park Stream, the Stoke Brook which rises at World's End north of Wendover and its largest tributary the Chalkshire Stream;
- the Wendover Arm feeder of the Grand Union Canal which starts within 1km of the route at Wharf Road, Wendover;

- numerous identifiable ponds and drains located outside the route alignment but within 1km of the route;
- three public water supply (PWS) abstractions and a number of private groundwater abstractions; and
- Weston Turville Reservoir Site of Special Scientific Interest (SSSI) is approximately 1.3km north of the route. The reservoir itself is situated in the Stoke Mandeville and Aylesbury area (CFA11) but its source catchment is within this area.

1.2.4 Key environmental issues relating to water resources include:

- the potential impact on groundwater quality and groundwater abstractions in Wendover and Wendover Dean; and
- the potential impact from the Wendover green tunnel on groundwater flow and water dependent habitats, particularly groundwater flow towards the Weston Turville Reservoir SSSI and the Stoke Brook (Aylesbury).

1.2.5 Where a residual effect or mitigation for water resources impacts has a consequent effect on ecology, this is discussed further in Volume 2, CFA Report 10, Section 7.

2 Stakeholder engagement

2.1.1 Consultation with the following stakeholders has been undertaken to inform the water resources assessment.

- the Environment Agency with regard to cuttings associated with the Proposed Scheme through this area, i.e. the Wendover green tunnel and Wendover north cutting and the potential impact on Weston Turville Reservoir SSSI;
- Buckinghamshire County Council, Wycombe District Council, Chiltern District Council and Aylesbury Vale District Council;
- private licensees by way of a questionnaire and requesting further information or a meeting to more accurately assess and understand any potential risks to private abstractions;
- Thames Water Utilities Limited over their PWS sources; and
- the Canal & River Trust (formerly British Waterways) and the Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust with regard to Weston Turville Reservoir SSSI.

3 Baseline data

3.1 General

- 3.1.1 The following section provides a current description of water resources including surface water and groundwater.
- 3.1.2 All water bodies in this area fall within the Chilterns sub-catchment of the Thames River Basin District (RBD) as defined under the Water Framework Directive¹ (WFD) and are covered by the River Basin Management Plan² (RBMP).

3.2 Surface water

- 3.2.1 All surface water features within 1km of the route are presented in Table 1.
- 3.2.2 The current surface water baseline and water features with codes listed in Table 1 are shown in Maps WR-01-012 and WR-01-013 (Volume 5, Water resources and flood risk assessment Map Book). The map reference is in one of two forms. If the feature has a specific reference number then this is provided (e.g. a surface water crossing will be referenced as SWC-CFA10-01). If the feature has no specific reference its location on a specific map is provided (e.g. WR-01-012, D6) where D6 is a grid reference using the map specific grid.
- 3.2.3 The surface water features are based on the Environment Agency's Detailed River Network (DRN) with the addition of water bodies noted on the Ordnance Survey's (OS) 'OS VectorMapDistrict'
- 3.2.4 The drainage network in the Wendover area is complicated by the extensive modification of the natural spring fed stream network which feed and bypass the Grand Union Canal and Weston Turville Reservoir SSSI. Section 5.2 of this report provides further details and stream names.

¹ Water Framework Directive - Directive 200/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Strasbourg, European Parliament and European Council.

² River Basin Management Plan, Thames River Basin District, Environment Agency (2009).

Table 1: Surface water features within 1km of the route in this study area.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m³/s)	Catchment area at crossing (km²)	Notes
Unnamed pond at Hunt's Green Farm, King's Lane	Isolated field pond will be approximately 490m east of route. There are three ponds, all just outside the construction boundary. (SWC-CFA10-01)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Eleven unnamed ponds – Hunt's Green / The Lee	Located approximately 500m-1km north-east of the route in the vicinity of Hunt's Green and The Lee. (CFA10-Po1)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Seven unnamed ponds – Rushmoor Wood	Will be approximately 200m-800m north and east of the route near Rushmoor Wood and Strawberry Hill Farm. (CFA10-Po2)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

³ Water-feature classifications: Section 113 of the Water Resources Act 1991 defines a main river as a watercourse that is shown as such on a main river map. Section 72 of the Land Drainage Act 1991 defines an ordinary watercourse as 'a watercourse that is not part of a main river'. Section 221 of the Water Resources Act 1991 defines a watercourse as including 'all rivers and streams, ditches, drains, cuts, culverts, dikes, sluices, sewers (other than public sewers) and passages through which water flows'. Main rivers are larger rivers and streams designated by Defra on the main river map and are regulated by the Environment Agency

⁴ Year may vary in different river basin management plans (RBMPs).

⁵ For examples of receptor value, see Table 43 in the Scope and Methodology Report (SMR) Addendum, Volume 5: Appendix CT-001-000/2.

⁶ Derived from National River Flow Archive(NRFA) data and catchment areas calculated using the Flood Estimation Handbook (FEH) - Centre for Ecology and Hydrology, (2009) Flood Estimation Handbook (FEH) CD-Rom Version 3.0. Q95 is the flow which is exceeded for 95% of the time (i.e. it is a low flow and the river will only have flows less than this for 5% of the time).

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Two unnamed ponds – Mayertorne Manor	Will be approximately 800m-850m west of the route near Mayortorne Manor. (CFA10-Po3)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – Kingsash	Will be approximately 800m east of the route near Kingsash. (CFA10-Po4)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.
Unnamed pond – Smalldean Farm	Will be approximately 600m east of the route on Smalldean Farm. (CFA10-Po5)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.
Drain at London Road	Unnamed drain will be approximately 160m north of the route, south of Wendover House School playing field passing under London Road.	Ordinary watercourse	No status class shown in RBMP – assumed status Good	No status class shown in RBMP – assumed status Good	Low	Not applicable	Not applicable	The drain appears to rise at London Road and is likely to be groundwater fed as there are a number of springs within Wendover (See Section 5.2 of this report for further details). The drain is conveyed under London Road, via a culvert. There are no other obvious surface water connections.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Hampden Pond	Will be approximately 160m north of the route, south-east of Wendover in Hampden Meadow recreation ground. (CFA10-Po6)	Ordinary watercourse	No status class shown in RBMP – assumed status Good	No status class shown in RBMP – assumed status Good	Moderate	Not applicable	Not applicable	The pond is connected to the drain at Church Lane/Grand Union Canal.
Unnamed pond – recreation ground near Witchell Road	Will be approximately 290m east of the route within the recreation ground between Witchell Road and Chapel Lane, Wendover. North of Hampden Pond. (CFA10-Po7)	Ordinary watercourse	No status class shown in RBMP – assumed status Good	No status class shown in RBMP – assumed status Good potential	Moderate	Not applicable	Not applicable	The pond is likely to be culverted to the drain at Church Lane/Grand Union Canal. The pond is not connected to any other surface water features in the catchment.
Drain at Church Lane, Wendover	Will be east of the route flowing south to north through Wendover, to the south of Wharf Road.	Main river	No status class shown in RBMP – assumed status Good	No status class shown in RBMP – assumed status Good Potential	High	Not applicable	Not applicable	The drain at London Road merges into the drain at Church Lane near Wendover House School. Thereafter the drain at Church Lane flows northwards to Wharf Road where the Grand Union Canal Wendover Arm commences and flows to the north-east. At Wharf Road the drain at Church Lane becomes Castle Park Stream and flows to the north-west, towards Weston Turville reservoir and a number of other watercourses flowing into and around the reservoir. The drain at Church Lane, to the south of Wharf Road, is classified as Heavily Modified. At Wharf Road the drain is culverted until Walnut Drive.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Grand Union Canal (Wendover Arm)	Will be east of the route flowing south to north from Wharf Road through Wendover.	Artificial	Grand Union Canal, Wendover Arm feeder (not a canal) (GB70610183) Good	Good potential	High	Not applicable	Not applicable	The Grand Union Canal Wendover Arm commences to the north of Wharf Road and flows to the north-east. The Grand Union Canal (Wendover Arm) is classified as an open, artificial channel (not a canal).
Castle Park Stream (merges into Willow Brook)	Castle Park Stream emerges from a culvert and will be approximately 930m north of the route in the northern of Wendover.	Main river	No status class shown in RBMP – assumed status Good	No status class shown in RBMP – assumed status Good	Moderate	Not applicable	Not applicable	Emerges from a culvert at St Agnes Gate, Wendover and flows north-west towards Weston Turville Reservoir. South of the culvert near Wharf Road, the drain is referred to as the drain at Church Lane. To the east of Stanhope Close to the north of Wendover, Castle Park Stream converges with the Willow Brook before they diverge with one stream flowing northwest and the other continuing northwards. Both flow towards and into the Weston Turville reservoir.
Wendover Brook	Will be east of the route flowing south to north through Wendover	Main river	Bear Brook and Wendover Brook (GB10603903080) Moderate	Good potential	High	Not applicable	Not applicable	Wendover Brook is a small watercourse which has been heavily modified in the Wendover area. The stream is diverted around the Weston Turville Reservoir.
Two unnamed ponds – Loudwater Farm	Will be approximately 200m north of the route, south of Loudwater Farm. (CFA10-Po8)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Two unnamed ponds – Wellwick Farm	Will be approximately 250m - 350m south of the route, north-west of Wellwick Farm. (CFA10-P09)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The ponds are not connected to any other surface water features in the catchment.
Unnamed pond – Nash Lee	Will be 70m south of the route near Nash Lee Road. (CFA10-P10)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond is not connected to any other surface water features in the catchment.
Field drain near Loudwater Farm	Will be approximately 650m north of the route flowing into the Stoke Brook near World's End.	Not applicable	Not applicable	Not applicable	Moderate	Not applicable	Not applicable	The drain emerges from groundwater fed springs and flows into the Stoke Brook.
Stoke Brook	Sourced in a field drain near a balancing pond on the A413 near World's End and flows less than 1km north-west and then turns along the CFA10 and CFA11 boundary, north-east to south-west.	Main river in its lower reach Ordinary watercourse in its upper reach	Stoke Brook Aylesbury (GB106039030320) Moderate	Good status (by 2015)	High	Not applicable	Not applicable	Stoke Brook is a small watercourse and a classified WFD surface water body up to World's End Farm.
Unnamed pond - Lower Meadow	On the boundary of CFA11, approximately 480m north of the route near Lower Meadow. (CFA10-P13)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	The pond appears to outflow into the Stoke Brook.

Water feature	Location description (Volume 5, Water resources and flood risk assessment Map Book, map reference)	Watercourse classification ³	WFD water body and current overall status	WFD status objective (by 2027 ⁴ as in RBMP)	Receptor value ⁵	Q95 ⁶ (m ³ /s)	Catchment area at crossing (km ²)	Notes
Chalkshire Stream	Rises south of the route near Chalkshire, flows past The Chilterns Brewery and Nashlee Farm, flows north into CFA11 (refer to Map WR-01-014. SWC-CFA11-01 for further information).	Main river	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good	Moderate	0.005	5.26	Flows north from Nash Lee before crossing the route on the CFA10/CFA11 boundary, then flowing north-east before joining the Stoke Brook.
Unnamed pond – Nashlee Farm	Will be approximately 600m south of the route near Nashlee Farm. (CFA10-P11)	Not applicable	Not applicable	Not applicable	Low	Not applicable	Not applicable	Isolated farm pond with no evident surface water links.
B4009 Nash Lee Road moat	Will be 600m south of the route at The Chiltern Brewery, south-east of B4009 Nash Lee Road. (CFA10-P12)	Ordinary watercourse	No status class shown in RBMP – assumed status Moderate	No status class shown in RBMP – assumed status Good	Moderate	Not applicable	Not applicable	Unnamed moat approximately 600m south of the route near Burnham Farm. The moat is connected to the Chalkshire Stream via an outlet channel in the north.

- 3.2.5 There are no surface water abstractions within 1km of the route in the study area⁷. There is the potential for unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.
- 3.2.6 Table 2 summarises surface water discharge consents within 1km of the route in the study area.

Table 2: Surface water discharge consents.

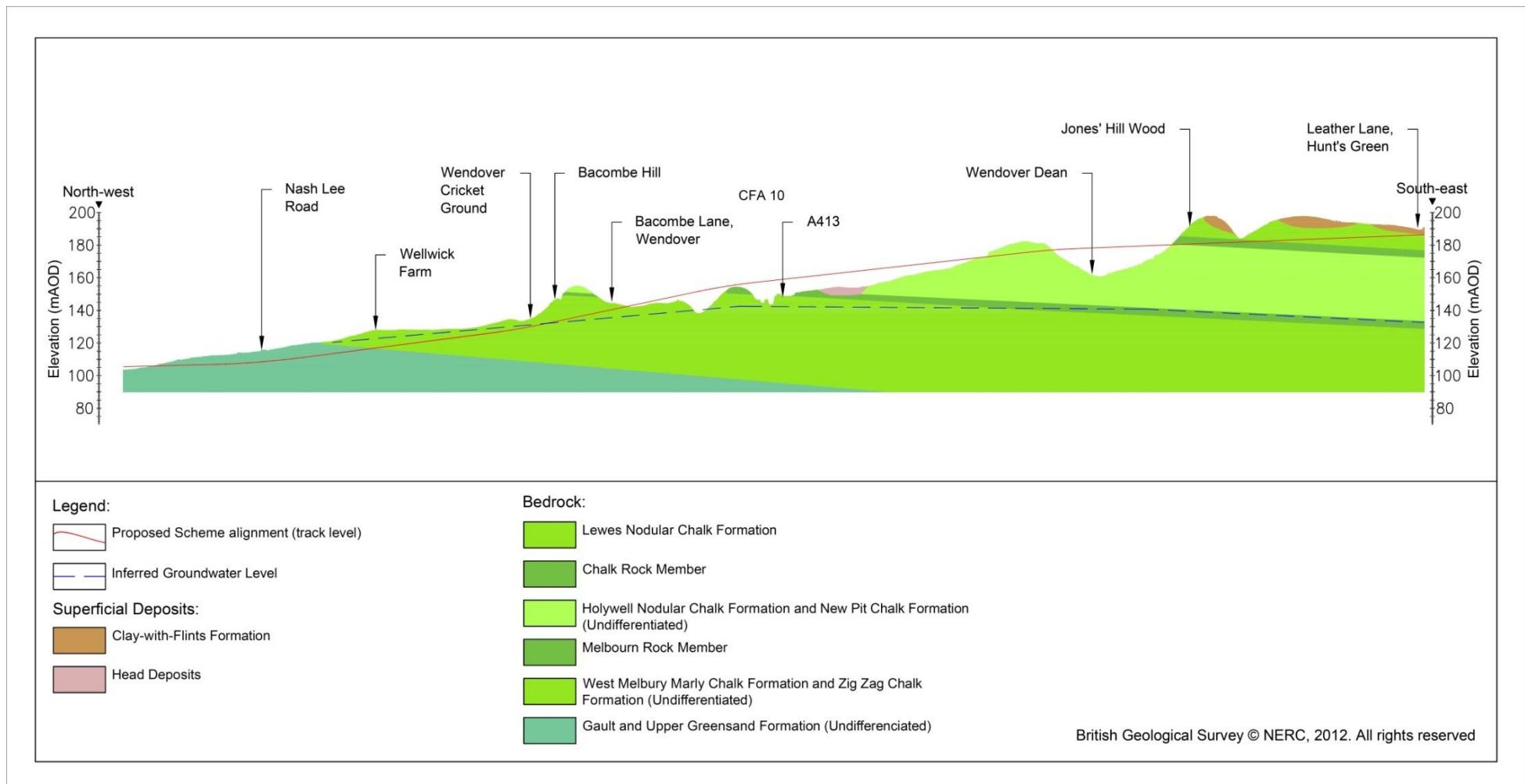
Reference number	Permit identifier	Distance (and direction) from route (in metres)	Discharge type	Receiving water body
CFA10WD15	CNTM.0332	610m (east)	Sewage discharge - final/treated effluent	Tributary of Stoke Brook
CFA10WD24	CNTW.0614	445m (east)	Sewage discharge - final/treated effluent	Loudwater Stream
CFA10WD42	CTWC.1107	795m (west)	Sewage discharge - final/treated effluent	Terrick Brook
CFA10WD93	CAWM.0259	350m (east)	Sewage discharge - final/treated effluent	Tributary of Loudwater Stream (permit indicates discharge onto land/into watercourse)
CFA10WD94	CAWM.0400	655m (east)	Sewage discharge - final/treated effluent	Tributary of Stoke Brook
CFA10WD95	CNTM.2112	850m (east)	Non-water company sewage (private)	Stoke Brook
CFA10WD104	CAWM.0717	310m (east)	Sewage discharge - final/treated effluent	Feeder drain of Hampden Pond
CFA10WD107	CANM.0883	320m (west)	Sewage discharge - final/treated effluent	Unnamed roadside ditch
CFA10WD124	NPSWQD002448	380m (east)	Sewage discharge - final/treated effluent	Tributary of River Thame
CFA10WD127	TEMP.0559	975m (east)	Sewage discharge - pumping station	Castle Park Stream
CFA10WD128	TEMP.2056	855m (west)	Sewage discharge - pumping station	Terrick Brook
CFA10WD129	TEMP.2057	825m (west)	Sewage discharge - pumping station	Terrick Brook
CFA10WD130	EPRGP3020XC	765m (west)	Sewage discharge - final/treated effluent	Unnamed tributary of Terrick Brook

⁷ Surface water abstractions for public supply are not included.

3.3 Groundwater

- 3.3.1 A summary of the geological units present in CFA10 along with their hydrogeological characteristics is presented in Volume 2, CFA Report 10, Section 13.3.
- 3.3.2 Map WR-02-010 (Volume 5, Water resources and flood risk assessment Map Book) illustrates the spatial distribution of the uppermost superficial and bedrock formations within CFA10.
- 3.3.3 A schematic cross-section along the line of the route in this study area with regard to geological strata, groundwater elevations (average, where known) and the Proposed Scheme is presented in Figure 1.
- 3.3.4 There are few superficial drift deposits within the study area, with the exception of a small area of Clay-with-Flints (Diamicton) to the east of the study area and a small area of Head Deposits of clay, silt, sand and gravel to the south of Wendover.
- 3.3.5 The bedrock geology of the majority of the study area comprises Cretaceous Chalk.
- 3.3.6 The undifferentiated Cretaceous Gault and Upper Greensand Formations comprise of mudstone, sandstone and limestone. These underlie the Chalk and outcrop in the northern 1km of the route in this study area.

Figure 1: Schematic geological cross-section for CFA10.



3.3.7 Table 3 summarises unlicensed and licensed groundwater abstractions (including PWS abstractions) or source protection zones (SPZ) located within 1km of the route in the study area. These are shown on Map WR-02-010 (Volume 5, Water resources and flood risk assessment Map Book). There is the potential for further unlicensed abstractions to exist, as a licence is not required for abstraction volumes below 20m³ per day.

Table 3: Groundwater abstractions in this study area.

Licence identifier (map reference number and Environment Agency reference)	Distance and direction from route (m)	Abstraction horizon	Maximum annual abstraction quantity (m ³)	Maximum daily abstraction quantity (m ³ /d)	Purpose	Number of boreholes
PWS (the reference number identifies the relevant SPZ¹⁸ on the maps)						
TH313 (licence identifier confidential)	SPZ ₁ will be 975m (south- west). SPZ ₂ will be crossed by the route in CFA10.	Chalk	732,000 (aggregate) (2,005 m ³ /d)	7,000 (aggregate)	PWS	Unknown
TH011 (licence identifier confidential)	SPZ ₁ will be 7.3km (south-east). SPZ ₃ will be crossed by the route in CFA10.	Chalk	2,555,000 (7,000 m ³ /d)	18,184	PWS	Unknown
TH316 (licence identifier confidential)	SPZ ₁ will be 3.4km (south-east), located in CFA9. SPZ ₃ will be crossed by the route in CFA10.	Chalk	1,000	5682.5	PWS	Unknown
Private licensed abstractions						
GWA23d (28/39/19/0217)	575m (north- east)	Chalk	7,200	Unknown	Drinking, cooking, sanitary, washing, small garden.	1

⁸ SPZ₁ is defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50m. SPZ₂ is defined by a 400 day travel time from a point below the water table with a minimum radius of 250m or 500m around the source, depending on the size of the abstraction and SPZ₃ is defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the final Source Catchment Protection Zone can be defined as the whole aquifer recharge area where the ratio of groundwater abstraction to aquifer recharge (average recharge multiplied by outcrop area) is >0.75. There is still the need to define individual source protection areas to assist operators in catchment management (Environment Agency, 2013).

Licence identifier (map reference number and Environment Agency reference)	Distance and direction from route (m)	Abstraction horizon	Maximum annual abstraction quantity (m ³)	Maximum daily abstraction quantity (m ³ /d)	Purpose	Number of boreholes
GWA24 (28/39/19/0218)	215m (north-east)	Chalk	5,110	Unknown	General farming and domestic (agriculture).	1
GWA2 (28/39/19/0160)	365m (north-east)	Chalk	4,795 (aggregate with GWA3)	Unknown	Industrial, commercial, public services supply to canal for throughflow).	1
GWA3 (28/39/19/0160)	320m (north-east)	Chalk	As GWA2	Unknown	Industrial, commercial, public services supply to canal for throughflow).	1
GWA20 (28/39/19/0155)	600m (north-east)	Chalk	1,659	Unknown	General farming and domestic (agriculture).	1
Private unlicensed abstractions						
CFA10-GWUAo1	735m (north-east)	Assumed to be Chalk.	Unknown	Unknown	Domestic	1
CFA10-GWUAo2	960m (south-west)	Assumed to be Chalk.	Unknown	Unknown	Unknown	1

- 3.3.8 A summary of groundwater discharge permits to groundwater directly or via land, within 1km of the route and their reference codes are listed in Table 4 and are shown on Map WR-02-010 (Volume 5, Water resources and flood risk assessment Map Book). Where the permit information indicates the receiving strata or groundwater body to be Chalk these may, in some cases, refer to undifferentiated Gault/Upper Greensand on Map WR-02-010 (Volume 5, Water resources and flood risk assessment Map Book). This apparent contradiction is a result of the two different data sets used and the lack of detailed boundaries for the Upper Greensand outcrop.

Appendix WR-002-010

Table 4: Discharge consents to groundwater.

Reference number	Permit identifier	Distance (and direction) from route (in metres)	Discharge type	Receiving strata/water body
CFA10WD3	CTCU.0710 (Revision due 2006)	445 (south west)	Domestic property - Sewage Discharges - Final/Treated Effluent - Not Water Company	Chalk
CFA10WD7	CNTW.1002	515m (south-west)	Public houses & bars - sewage discharges - final/treated effluent - not water company	Valley Gravels
CFA10WD8	CTWC.1125	195m (north-east)	Domestic property / recreational and cultural (CFA10WD16) - sewage discharges - final/treated effluent - not water company	Upper Greensand
CFA10WD11	CTWC.1907	520m (north-east)		Chalk
CFA10WD16	CTCU.1340	100m (north-east)		Chalk
CFA10WD17	CTCU.1609	505m (south-west)		Chalk
CFA10WD18	CTWC.0637	305m (south-west)		Chalk
CFA10WD19	CNTM.1192	475m (north-east)		Chalk
CFA10WD22	CNTM.1869	715m (south-west)		Chalk
CFA10WD23	CNTM.0870	355m (south-west)		Terrace Gravels
CFA10WD25	CTWC.0065	105m (north-east)		Chalk
CFA10WD28	CTCU.1583	380m (north-east)	Recreational and cultural - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD29	CNTW.0170	585m (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD30	CTWC.2131	200m (south-west)	Undefined - sewage discharges - final/treated effluent - not water company	Valley Gravel
CFA10WD33	CATM.2767	610m (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD35	CTWC.1609	60m (south-west)		Chalk
CFA10WD37	CTWC.1891	295m (north-east)		Upper Greensand
CFA10WD43	CTWC.1066	670m (south-west)	Horticultural establishment, nursery gardens - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD45	CNTM.0261	525m (north-east)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD46	CNTM.1872	560m (north-east)		Chalk
CFA10WD89	Canm.0103	680m (south-west)		Chalk
CFA10WD90	Cntm.1841	715m (south-west)		Chalk
CFA10WD103	Cawm.0362	285m (south-west)	Domestic tip - sewage discharges - final/treated effluent - not water company	Into land
CFA10WD105	Canm.0858	720m (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Groundwater (via soakaway)

Reference number	Permit identifier	Distance (and direction) from route (in metres)	Discharge type	Receiving strata/water body
CFA10WD3	CTCU.0710 (Revision due 2006)	445m (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk
CFA10WD108	Cawm.1154	On route	Education- sewage discharges - Final/treated effluent - not water company	Groundwater (via soakaway)
CFA10WD115	Canm.1036	725m (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Chalk
CFA10DW117	Ctcu.0710	445m (south-west)		Chalk
CFA10DW120	Cntw.0081	235m (south-west)		Chalk
CFA10DW122	Cntm.1430	40m (north-east)	Recreational and cultural - sewage discharges - final/treated effluent - not water company	Chalk
CFA10DW123	Npdwqdo02004	820m (south-west)	Domestic property - sewage discharges - final/treated effluent - not water company	Groundwater (via borehole)

3.4 Surface water/groundwater interaction

3.4.1 Table 5 summarises the surface water/groundwater interactions within 1km of the route.

Table 5: Surface water/groundwater interaction.

Location description	Distance (m) and direction from route	Formation	Approximate elevation (metres above ordnance datum, m AOD)	Comments
Weston Turville Reservoir	1,100m (north).	Upper Greensand	95 - 105m AOD	<p>The reservoir has several sources of supply, including from the Grand Union Canal Wendover Arm. The Wendover Brook has been diverted to flow around the western margin of the reservoir.</p> <p>Although this feature is more than 1km from the centreline, it could be impacted indirectly by changes to the hydrological and hydrogeological regimes linked to the Wendover Brook (see below).</p>
Wendover Brook	365m (north-east)	Chalk	120 – 125m AOD	<p>The brook emerges within the western residential area of Wendover and flows towards Weston Turville Reservoir before circumventing the reservoir and flowing to join the Bear Brook to the north-west of Aylesbury.</p> <p>The stream is likely to be groundwater spring fed.</p>

Location description	Distance (m) and direction from route	Formation	Approximate elevation (metres above ordnance datum, m AOD)	Comments
Drain at Church Lane/Grand Union Canal (Wendover Arm)	380m (north-east)	Chalk	125 - 130m AOD	This stream emerges from groundwater spring fed ponds in Hampden Park and the drain at London Road in the vicinity of school grounds to the south-west of Wendover and feeds into the Grand Union Canal, Wendover Arm and Castle Park Stream.
Castle Park Stream and Willow Brook	930m (north-east)	Chalk	115 - 120m AOD	The Castle Park Stream emerges from culvert in the north-west of Wendover, within a residential area. The stream feeds into the Weston Turville Reservoir. The stream is likely to be groundwater spring fed.
Field drain near Loudwater Farm	480m (north-east)	Gault Formation and Upper Greensand	105 – 110m AOD	Although this appears to emerge on top of the low permeability Gault Formation and Upper Greensand it may actually spring up closer to the Chalk/Gault boundary. The stream is likely to be groundwater spring fed.
Field drain at World's End and Stoke Brook	635m (north-east)	Gault Formation and Upper Greensand	105 - 110m AOD	Although this drain appears to emerge on top of the low permeability Gault Formation and Upper Greensand it may actually spring up closer to the Chalk/Gault boundary. This starts as a small tertiary stream but is classified as part of the Stoke Brook (Aylesbury) WFD water body. The stream is likely to be groundwater spring fed.
Drain at Church Lane /Grand Union Canal (Wendover Arm)	380m (north-east)	Chalk	125 - 130m AOD	This stream emerges from groundwater spring fed ponds in Hampden Park and the drain at London Road in the vicinity of school grounds to the south-west of Wendover and feeds into the Grand Union Canal, Wendover Arm and Castle Park Stream.

Water dependent habitats

3.4.2 Table 6 summarises the water dependent designated habitat within 1km of the route.

The table identifies where a water dependency exists but the assessment of impact on water dependent ecology receptors is found in the Volume 2, CFA Report 10, Section 7.

Table 6: Description of water dependent habitats.

Name/ location	Distance	Designation	Comments
Weston Turville Reservoir	1.1km (north of Proposed Scheme)	SSSI	<p>Historically, Weston Turville Reservoir was built to mitigate for spring flows in the Wendover area that are captured for filling the Grand Union Canal.</p> <p>The SSSI is designated for reed beds and lowland fen, (both of which are habitats of principal importance), rare plants (including mudwort, orange foxtail and grey club rush), wintering birds, and some notable aquatic invertebrates.</p>

4 Site specific surface water assessment

4.1 Summary of assessment

- 4.1.1 Table 7 summarises the potential impacts and effects, both significant and not significant, to surface water features from the Proposed Scheme in the study area. Only those impacts and effects that are classed as significant are presented in Volume 2, CFA Report 10, Section 13.4.
- 4.1.2 Table 7 only includes water features which could potentially be impacted by the Proposed Scheme. Features such as isolated ponds and drains which will lie outside the construction footprint and area of impact of the Proposed Scheme are not included. Details of these features are, however, provided in Table 1. Map references refer to those presented on Maps WR-01-012 to WR-01-013 (Volume 5, Water resources and flood risk assessment Map Book).
- 4.1.3 The draft Code of Construction Practice⁹ (CoCP) referred to in Table 7 sets out the measures and standards of work that will be applied to the construction of the Proposed Scheme (see Volume 5: Appendix CT-003-000/1).
- 4.1.4 The proposed scheme has been designed to control impacts on the water environment during operation through drainage design incorporating sustainable drainage systems (SuDS) features and by following best practice pollution control guidance as agreed with the Environment Agency. As a result, there are no potentially significant impacts identified during the operation phase.

⁹ Arup/URS, (2013), Phase One: Draft Code of Construction Practice. London, HS2 Ltd.

Table 7: Summary of potential impacts to surface water.

Surface water feature/receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Wendover Brook, Grand Union Canal and Feeders	High	Wendover green tunnel Wendover north cutting	The Wendover Brook, Grand Union Canal and feeder streams will not be crossed in this study area. There could be a change to stream flows as a result of changes to groundwater levels and baseflow to the streams due to the green tunnel and cutting.	Negligible impact Neutral effect (Not significant)	No further mitigation considered necessary.	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

Surface water feature/receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Stoke Brook	High	Wendover north cutting	Interception of groundwater flow to field drains at World's End that feed the Stoke Brook. This could result in reduced flow in these surface water features. (see Section 5.2)	Minor impact Moderate effect (Significant)	Drainage will return the majority of flow approximately 1km downstream of where the drains emerge. No practicable means of feeding the drains further upstream have been identified.	Minor impact Moderate effect (Significant)	No further practical mitigation measures can be implemented. At the scale of the wider Stoke Brook the effect is considered neutral. Subject to monitoring outcomes, further mitigation options include measures to discharge intercepted groundwater via local infiltration on the northern side of the Wendover north cutting. With the implementation of such measures, if necessary, there will be no permanent significant effect on the Stoke Brook.	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Drain at London Road, Wendover	Low	Small Dean viaduct Small Dean north embankment	The embankment could restrict natural infiltration and run-off to the London Road Drain.	Moderate impact Slight effect (Not significant)	Drainage design will include the discharge of track and land drainage to the source of the London Road drain.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (Permanent)

Surface water feature/receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact and effect	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Unnamed pond – Nash Lee (CFA19-P10)	Low	Land potentially required during construction, adjacent to Wendover north cutting.	The intention is to retain this highway drainage balancing pond. There will be no significant effect on water resources.	Negligible impact Neutral effect (Not significant)	Covered by land acquisition compensation.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)
Two unnamed ponds – Wellwick Farm (CFA10-P09)	Low	Land potentially required during construction, adjacent to Wendover north cutting.	One of the ponds could be lost if the overhead power lines are restrung - but there is potential to avoid impact and protect the pond. There will be no significant effect on water resources.	Negligible impact Neutral effect (Not significant)	Covered by land acquisition compensation.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

4.2 Detailed assessments

Drainage proposals

- 4.2.1 The Proposed Scheme has been designed to control impacts on the water environment during operation through appropriately designed surface drainage (i.e. incorporating sustainable urban drainage systems, SuDS) and by following best practice pollution control guidance, as agreed with the Environment Agency. South of Wendover interception ditches on the uphill side of the cuttings will be channelled into nearby balancing ponds which will act as soakaways.
- 4.2.2 North of Wendover, balancing ponds will have a more traditional function of reducing peak runoff before water is discharged into the receiving watercourses which are understood to have a strong spring fed component of baseflow.
- 4.2.3 As a result of the above, there are no potentially significant impacts on surface water from land drainage identified during the operation phase.
- 4.2.4 Balancing ponds are further discussed under the groundwater section (Section 5.2) of this report, as groundwater will be either the receptor for the surface water drainage or the source of water intercepted in cuttings.

5 Site specific groundwater assessment

5.1 Summary of assessment

- 5.1.1 Table 8 summarises the potential to hydrogeology (groundwater), abstractions from groundwater, water dependent habitats and surface water/groundwater interactions. Only those impacts and effects that are assessed as significant are presented in Volume 2, CFA Report 10, Section 13.4.
- 5.1.2 The draft Code of Construction Practice (CoCP), referred to in Table 8, sets out the measures and standards of work that will be applied to the construction of the Proposed Scheme (see Volume 5: Appendix CT-003-000/1).

Table 8: Summary of potential impacts to groundwater receptors.

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Hydrogeology (groundwater)									
Chalk Principal aquifer	High	Earthworks stockpiles at: Hunt's Green Farm Small Dean viaduct embankments (north and south) Wendover Dean viaduct embankments (north and south)	Deposition of embankment material on the Chalk outcrop may reduce groundwater recharge. The area for deposition of embankment material is minimal compared to the recharge area of the Chalk. The stockpile material will comprise a significant proportion of excavated Clay-with-Flints and will be underlain by this formation. Infiltration and run-off will be similar to the existing condition.	Minor impact Slight effect (Not significant)	Rainfall on the route will be collected by drainage systems and diverted to nearby ditches and swales. Infiltration through these systems will give rise to recharge close to the route, and the area that would have been recharged naturally previously.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Infiltration basins; north of Leather Lane, east of A413 London Road, two basins south and north of Bowood Lane, three basins near Rocky Lane and small basin north of Bacombe Lane	Very unlikely to adversely impact groundwater quality, due to the unsaturated thickness of the Chalk and attenuation of any constituents within the drainage water. Further information is provided in Section 5.2 of this report.	Negligible impact Neutral effect (Not significant)	None required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable
Head Secondary aquifer	Moderate	Small Dean viaduct and southern approach embankment	Shallow groundwater in superficial deposits is only likely to be present in the Head Deposits in the area of the Small Dean viaduct and its southern embankment. Construction could impact local flows and groundwater quality.	Minor impact Slight effect (Not significant)	With implementation of the draft CoCP (Sections 12 and 16), shallow groundwater quality and flow in the Head Deposits are unlikely to be significantly impacted by construction in this area.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Wendover green tunnel (southern section)	The southern part of tunnel from approximately the cricket ground at Wendover southwards is likely to be above groundwater levels. As such there is unlikely to be a significant impact to groundwater. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	With implementation of Section 16 of the draft CoCP mechanisms will be in place to ensure groundwater quality is not adversely impacted from construction activities.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)
Chalk Principal aquifer	High	Wendover green tunnel (northern section)	The northern part of tunnel from approximately the cricket ground at Wendover northwards is likely to be below groundwater levels. As such there is potential to impact groundwater quality and flows. See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	With implementation of Section 16 of the draft CoCP mechanisms will be in place to ensure groundwater quality is not adversely impacted from construction activities. Pre- and post-construction monitoring.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (permanent) Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Chalk Principal aquifer	High	Wendover north cutting	The cutting will be below the existing road and rail infrastructure to the north of the Proposed Scheme and the limited data available indicate that groundwater levels are likely to be above the base of the scheme. As such, there is potential for groundwater quality and flows to be affected. See Section 5.2 of this report for further details.	Minor impact Moderate effect (Significant)	With implementation of Section 16 of the draft CoCP and best practice, mechanisms will be in place to ensure groundwater quality is not adversely impacted from construction activities.	Negligible impact Neutral effect (Not significant)	None	Negligible impact Neutral effect (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Abstractions									
PWS (SPZ TH313)	High	Wendover Dean viaduct and embankments Rocky Lane cutting Small Dean viaduct and embankments Balancing ponds	The route will be above the groundwater level and as such groundwater quality and flows are unlikely to be significantly affected. There is a potential for infiltration from balancing ponds to pollute Chalk groundwater in SPZ areas. Water in track drainage or from intercepted land drainage is not expected to contain significant amounts of pollutants and the base of pond material and vegetation together with the thickness of unsaturated Chalk will provide attenuation of any substances within the drainage water.	Minor impact Slight effect (Not significant)	With implementation of Sections 12 and 16 of the draft CoCP mechanisms will be in place to avoid adversely impacting water quality through construction activities. Balancing ponds generally avoid being sited over SPZ1.	Negligible impact Neutral effect (Not significant)	None	None	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Private abstractions (GWA23d, GWA24, GWA2, GWA3, GWA20) (refer to Table 3 for licence references)	High	Small Dean viaduct and embankments Wendover green tunnel	The route will be above the groundwater level and as such groundwater quality and flows are unlikely to be significantly affected. However, within the vicinity of the cricket ground to the south of Wendover, groundwater levels may be above the route. See Section 5.2 of this report for further details.	Moderate impact Moderate effect (Significant)	With implementation of Sections 12 and 16 of the draft CoCP mechanisms will be in place to avoid adversely impacting water quality through construction activities.	Moderate impact Moderate effect (Significant)	At licensed private water abstractions where there is the potential for significant adverse effects on abstractions during construction, monitoring of groundwater turbidity will be used to verify if effects are occurring and provide evidence to justify further intervention, should that be required. Appropriate mitigation measures will be agreed with the owner in advance of construction commencing and may, for example, consist of the provision of a temporary alternative supply.	Negligible impact Neutral effect (Not significant)	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Surface water/groundwater interaction									
Drain at Church Lane and drain at London Road (380m north-east of route)	Moderate	Small Dean viaduct northern approach embankment	<p>These spring-fed streams emerge from ponds in Hampden Meadow and within the vicinity of school grounds to the south-west of Wendover.</p> <p>The groundwater levels are considered to be below the route and hence the flow will not be intercepted.</p> <p>See Section 5.2 of this report for further details.</p>	<p>Negligible impact Neutral effect (Not significant)</p>	Not required	<p>Negligible impact Neutral effect (Not significant)</p>	None	None	Not applicable
Castle Park Stream and Willow Brook (930m north-east of the route)	Moderate	Wendover green tunnel	<p>Where the groundwater catchment passes under the route, the groundwater levels are likely to be below the route and hence the spring fed stream will not be affected.</p> <p>See Section 5.2 of this report for further details.</p>	<p>Negligible impact Neutral effect (Not significant)</p>	Not required	<p>Negligible impact Neutral effect (Not significant)</p>	None	None	Not applicable

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Wendover Brook (365m north-east of the route)	High	Wendover green tunnel	<p>Baseflow in the stream is likely to be groundwater fed and some shallow groundwater flow to springs will be intercepted although the majority of the aquifer supplying the springs will remain unaffected below the route.</p> <p>This will be a short term, reversible impact.</p> <p>When the Wendover green tunnel is completed groundwater flow will not be intercepted to the same degree, and it is predicted impacts will be negligible.</p> <p>See Section 5.2 of this report for further details.</p>	<p>Negligible impact Neutral effect (Not significant)</p>	<p>The Proposed Scheme will transfer any intercepted flow into the headwaters of the Stoke Brook during construction. After construction the green tunnel will be sealed and no drainage of significance will be required.</p>	<p>Negligible impact Neutral effect (Not significant)</p>	None	None	Construction (temporary)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Field drain near Loudwater Farm	Moderate	Wendover north cutting	Since this may be fed by groundwater from the Chalk/Gault boundary, the drainage in the cutting may intercept groundwater flow and reduce the baseflow. See Section 5.2 of this report for further details.	Minor impact Slight effect (Not significant)	None required	Minor impact Slight effect (Not significant)	None	Minor impact Slight effect (Not significant)	Construction (permanent)
Field drain at World's End and Stoke Brook	High	Wendover north cutting	Since this may be fed by groundwater from the Chalk/Gault boundary, the drainage in the cutting may intercept groundwater flow and reduce the baseflow. This stream/drain is classified as a main river (Table 1) and as such has a high value. Flows are likely to be reduced in the upper 1km of the stream/drain. See Section 5.2 of this report for further details.	Minor impact Moderate effect (Significant)	Drainage will return the majority of flow approximately 1km downstream of where the stream/drain emerges. Specific monitoring of groundwater levels and watercourse flows will be used to verify if impacts are occurring	Minor impact Moderate effect (Significant)	Discussions will be held with the Environment Agency on the results of the monitoring to determine if any further mitigation is required. Subject to monitoring outcomes, further mitigation options could include measures to discharge intercepted groundwater via local infiltration on the northern side of the Wendover north cutting. With the implementation of such measures, if necessary, there will be no permanent significant effect on the Stoke Brook.	Negligible impact Neutral effect (Not significant)	Construction (permanent)

Receptor	Receptor value	Design element	Discussion of potential impact to water receptor	Magnitude of potential impact	Avoidance and mitigation measures included in design	Magnitude of remaining impact and effect	Other mitigation measures	Residual effect	Duration of effect
Water dependent habitats									
Weston Turville Reservoir SSSI	High	Wendover green tunnel Wendover north cutting	The reservoir sits above the Gault Formation/Upper Greensand which are unproductive strata. The reservoir is supplied by spring fed streams, and as described above, these are unlikely to be disturbed by the route. As such there should be no impact to the reservoir. See Section 5.2 for further details.	Negligible impact Neutral effect (Not significant)	None required	Negligible impact Neutral effect (Not significant)	None	None	Not applicable

5.2 Detailed assessments

- 5.2.1 The following sub-sections present the detailed assessment based on the available data of the potential for impacts on groundwater flow and groundwater quality resulting from the construction of the route in the immediate vicinity of Wendover.
- Cuttings assessment**
- 5.2.2 An assessment of the potential impacts from cuttings in this study area is summarised in Table 9 and discussed in more detail in the subsequent sub-sections.
- 5.2.3 Since the Clay-with-Flints is not classed as an aquifer, interception of any seepages (issues) that may occur towards the tops of the side slopes in the South Heath cutting is assessed as not having a significant impact on water resources.
- 5.2.4 As the Wendover north cutting and Wendover green tunnel are adjacent to one another and the temporary affect to groundwater flows and levels will be as a result of a combination of these elements, they have been discussed together. A summary of the parameters applied to determine the zone of influence is provided in Table 9.

Table 9: Summary of cuttings in this study area.

Cutting name	Geology penetrated	Groundwater elevation	Effect on groundwater resources	Mitigation required
South Heath cutting (continues from CFA9)	Chalk Principal aquifer	Below the cutting.	No interception of Chalk groundwater.	None required
Wendover green tunnel	Chalk Principal aquifer	Below the tunnel invert for southernmost 600m. Above the tunnel invert for the northernmost 700m.	Zone of influence indicates no springs or other groundwater receptors will be affected significantly. See subsequent sub-sections of this report for further details.	None required
Wendover north cutting	Chalk Principal aquifer (for the southernmost 550m). Upper Greensand (northernmost 950m).	Above the cutting.	Zone of influence does not contain springs or other groundwater receptors. The potential impacts on the Stoke Brook will be mitigated via the mitigation options described in Table 7 and 8 and are not considered significant. See subsequent sub-sections of this report for further details.	No practicable mitigation identified

Cuttings/green tunnel	Hydraulic conductivity, k (m/s)	Reference	Range of dewatering depths, h (m)	Maximum distance from route for zone of influence (m)
Wendover green tunnel	0.00023	British Geological Survey, BGS (1997) ¹⁰	0 - 4	122
Wendover north cutting	As above	As above	As above	As above

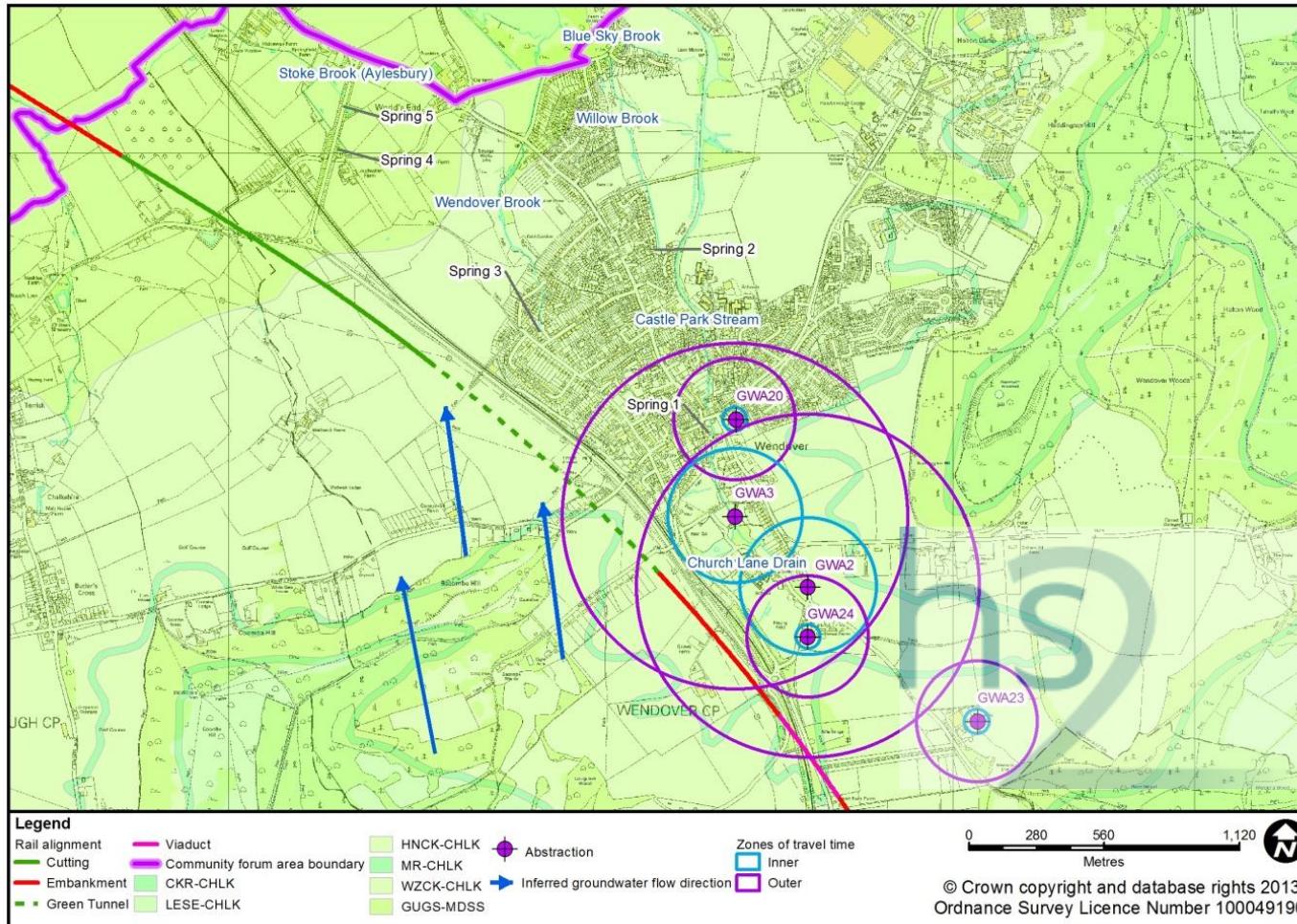
Groundwater receptors close to Wendover

5.2.5 The receptors of interest are shown on Figure 2 and comprise:

- spring fed stream 1, the drain at Church Lane, emerging from ponds in Hampden Meadow and the drain at London Road in the vicinity of school grounds in south-west Wendover, will be approximately 380m north-east of the route and feeds into the Grand Union Canal, Wendover Arm;
- spring fed stream 2/Castle Park Stream emerging from a culverted extension of the drain at Church Lane within residential area in north-west Wendover, will be approximately 930m north-east of the route and merging with the Willow Brook;
- spring fed stream 3/Wendover Brook emerging within residential area in western Wendover, and will be approximately 365m north-east of the route;
- spring fed stream 4 (unnamed) near Loudwater Farm and likely to emerge from Gault Formation and Upper Greensand/Chalk boundary to the west of Wendover, and will be approximately 480m north of the route;
- spring fed stream 5/Stoke Brook near World's End, will be approximately 635m north of the route; and
- five licensed groundwater abstractions in Wendover.

¹⁰ British Geological Survey (BGS), (1997), *The aquifer properties of major aquifers in England and Wales. Technical Report WD/97/34*, Environment Agency R&D Publication 8.

Figure 2: Location of spring fed streams and abstractions relative to the Wendover green tunnel and Wendover north cutting¹¹



¹¹ Key to geology: CKR-CHLK = Chalk Rock Member, LESE-CHLK = Lewes Nodular Chalk Formation and Seaford Chalk Formations (Undifferentiated), HNCK-CHLK = Holywell Nodular Chalk Formation and New Pit Chalk Formation (Undifferentiated), MR-CHLK = Melbourn Rock Member, WZCK-CHLK = West Melbury Marly Chalk Formation and Zig Zag Chalk Formation (Undifferentiated) and GUGS-MDSS = Gault Formation and Upper Greensand Formation (Undifferentiated).

Water table position relative to the route

- 5.2.6 The potential for impacts depends on the position of the water table relative to the route:
- in the temporary condition during construction the cutting would act as a drain where the cutting is below the water table. During this condition there will be drawdown of surrounding groundwater and interception of groundwater flows leading to reductions in springs flows down gradient of the route;
 - once the Wendover green tunnel is completed the walls and invert will be sealed and so there is potential for obstruction of groundwater flow if it is below the water table; and
 - there is the potential to affect water quality downstream of the route (including areas where works will be above the water table since contaminants could percolate through the unsaturated zone).
- 5.2.7 Although the groundwater table position will vary naturally due to seasonal effects it will be locally controlled by the elevations of flowing springs. In extreme droughts the groundwater table may drop below the springs which will then dry up; in extreme floods the groundwater elevation may be controlled by ground levels in dry valleys if groundwater flooding occurs. The water table position has not been monitored at Environment Agency observation boreholes in the vicinity of the route. Therefore the following elevation data have been used taking into account the contours shown on the BGS South West Chilterns Hydrogeology map (1978)¹²:
- 135m AOD at spring source of stream 1 (from 1:25,000 OS map);
 - 123m AOD at spring source of stream 2/Castle Park Stream and Willow Brook and stream 3/Wendover Brook (from 1:25,000 OS map);
 - 112m AOD at spring source of streams 4 and 5/Stoke Brook (Aylesbury) (from 1:25,000 OS map);
 - 133m AOD at a private borehole south of Wendover, 240m south-west of the route (from BGS borehole records); and
 - 131m AOD at private borehole west of Wendover at Butler's Cross, 1.6km south-west/west of route (from BGS borehole records).
- 5.2.8 The inferred water table elevations under normal conditions and the route are compared on Figure 3 and Figure 4.

¹² British Geological Survey (BGS), (1978), South West Chilterns Hydrogeological Map. Product code HY07F, ISBN: 0751811823.

Figure 3: Conceptual cross-section of groundwater flow at Wendover green tunnel and north cutting, northern part

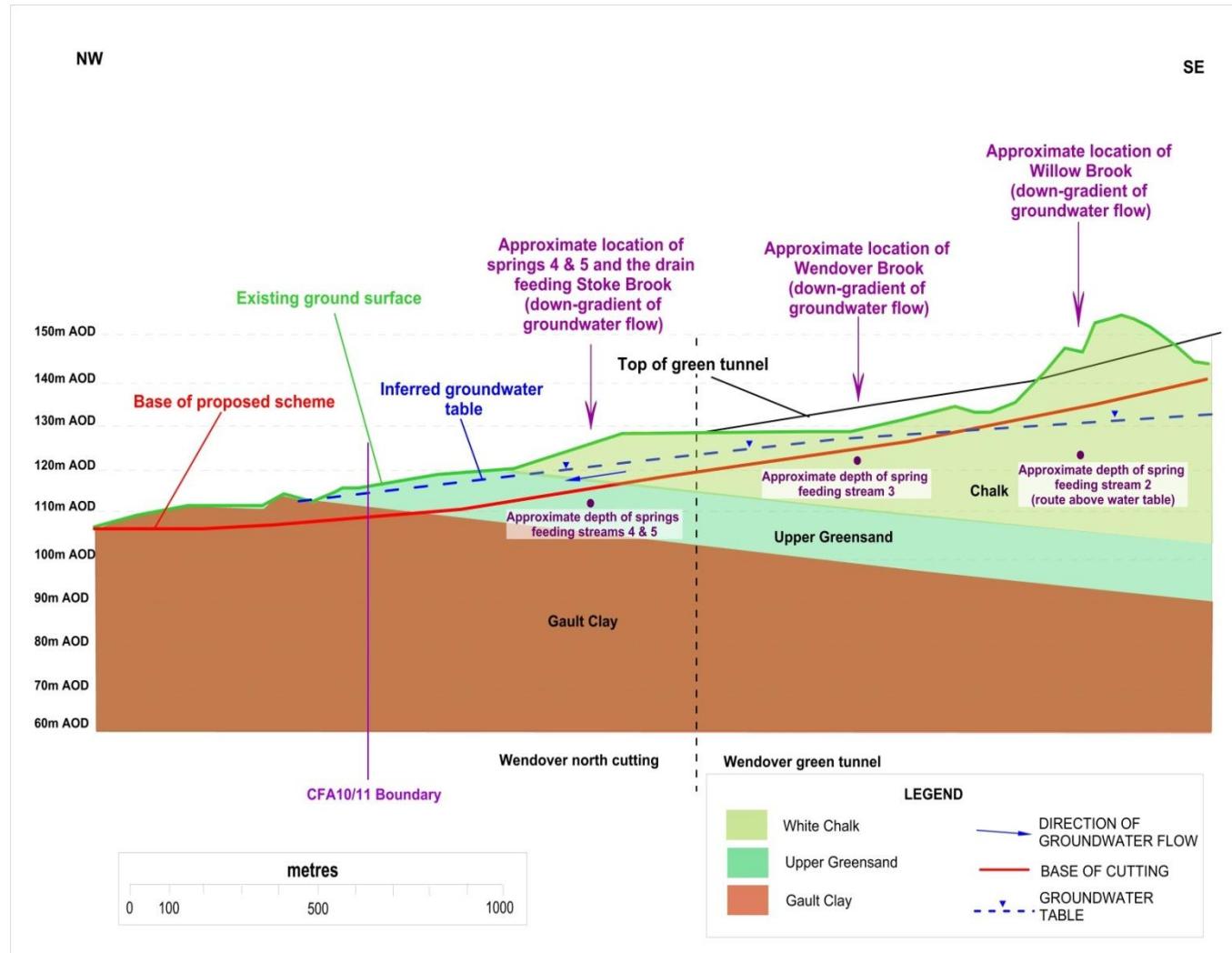
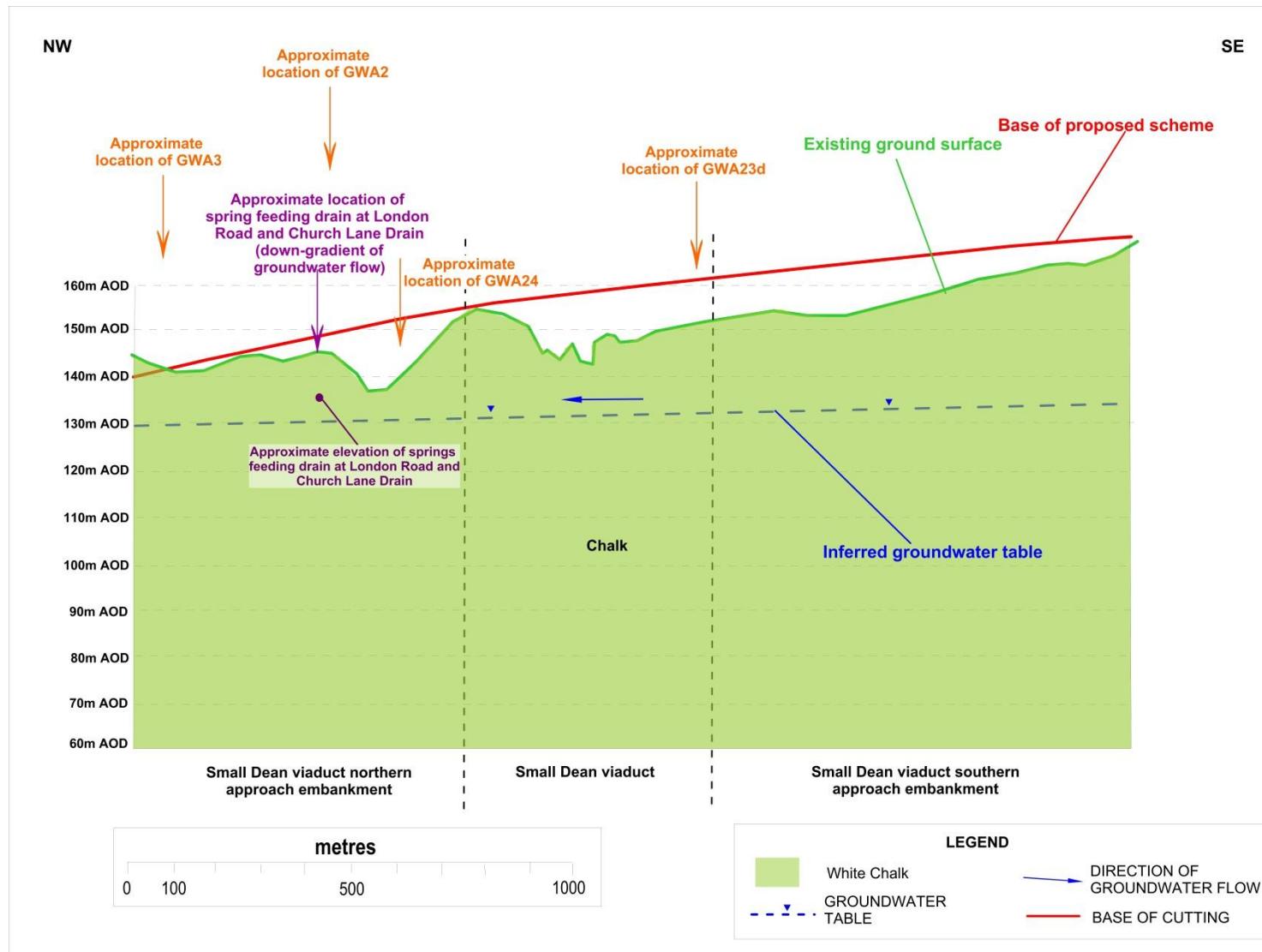


Figure 4: Conceptual cross-section of groundwater flow at Wendover green tunnel and north cutting southern part



Drawdown impacts on groundwater from cuttings and the green tunnel

- 5.2.9 The Wendover green tunnel and Wendover North cutting are inferred to be below the groundwater table from about the cricket ground (immediately opposite the existing railway station in Wendover) northwards. Groundwater flow will therefore be intercepted from around this area as it flows north-westwards along the route to the point where the aquifer thins out and disappears at the Gault Clay outcrop.
- 5.2.10 In order to establish the extent to which dewatering may cause drawdown and affect the groundwater flow regime, Sichardt's formula has been used to predict drawdowns following guidance in Construction Industry Research and Information Association, CIRIA C515 (2000)¹³ and CIRIA C113 (1986)¹⁴. Sichardt's formula is presented below:

$$L_o = C \times h \times \sqrt{k}$$

Where:

L_o = distance of influence from linear structure (m)

k = hydraulic conductivity (m/s)

h = drawdown (m)

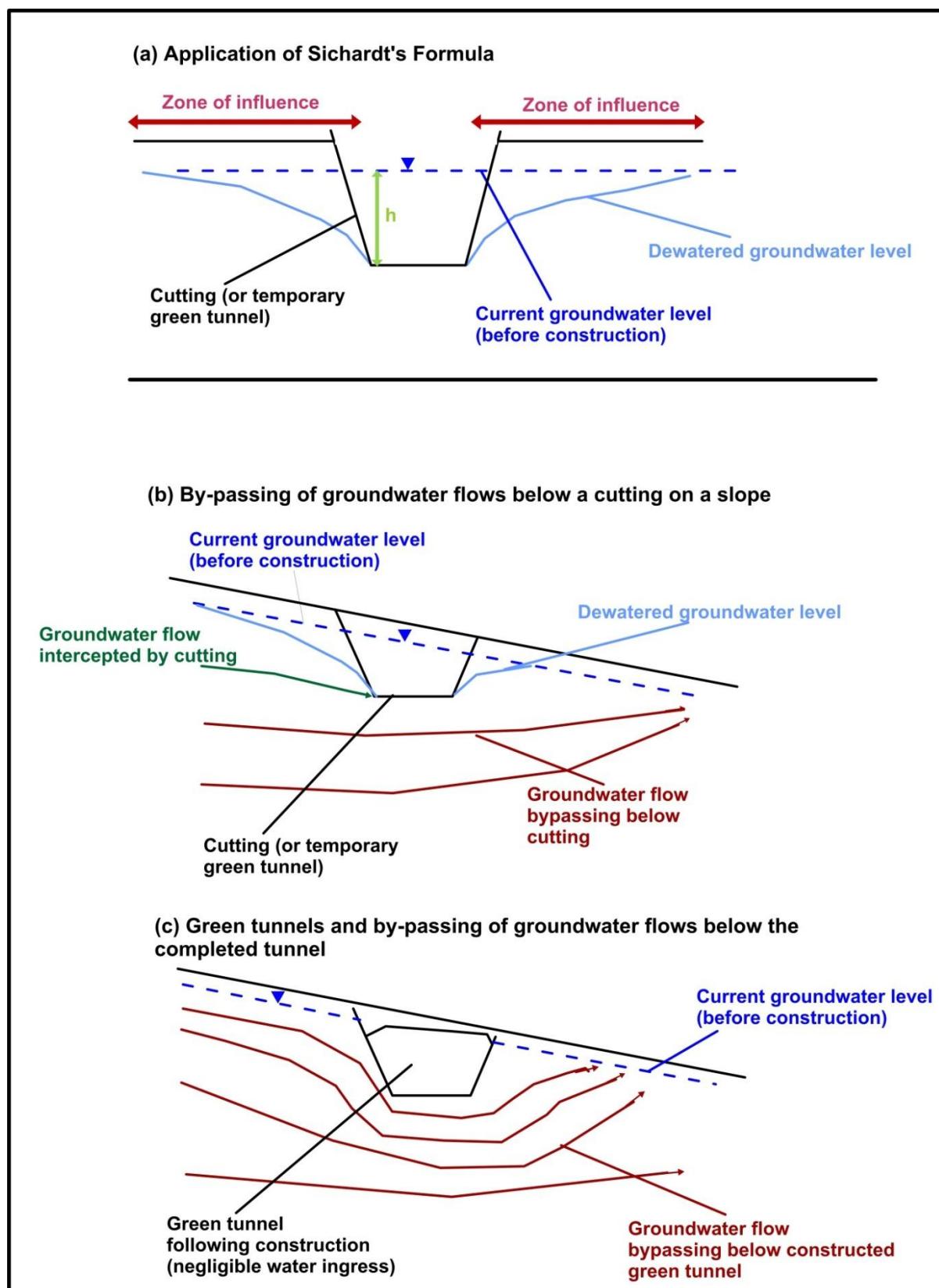
C = empirical factor taken to be 2000

- 5.2.11 Where the base of the cutting or green tunnel is close to or at the inferred groundwater table any dewatering will be minimal, with the zone of influence being close to the route. Where the base of the scheme is at the maximum depth below the water table (e.g. 4m) the extent of dewatering will extend furthest from the route. Figure 5 illustrates schematically how Sichardt's formula has been applied and how the completed cutting and green tunnel will affect the groundwater flow regime:
- panel (a) shows the drawdown around a cutting in an aquifer with a horizontal watertable;
 - panel (b) shows how in an area of flowing groundwater, some flow will bypass a cutting even though this is acting as a drain; and
 - panel (c) shows how flows will redistribute around a tunnel in the operational, permanent case once it is sealed.

¹³ CIRIA, (2000), CIRIA C515: Groundwater control – design and practice.

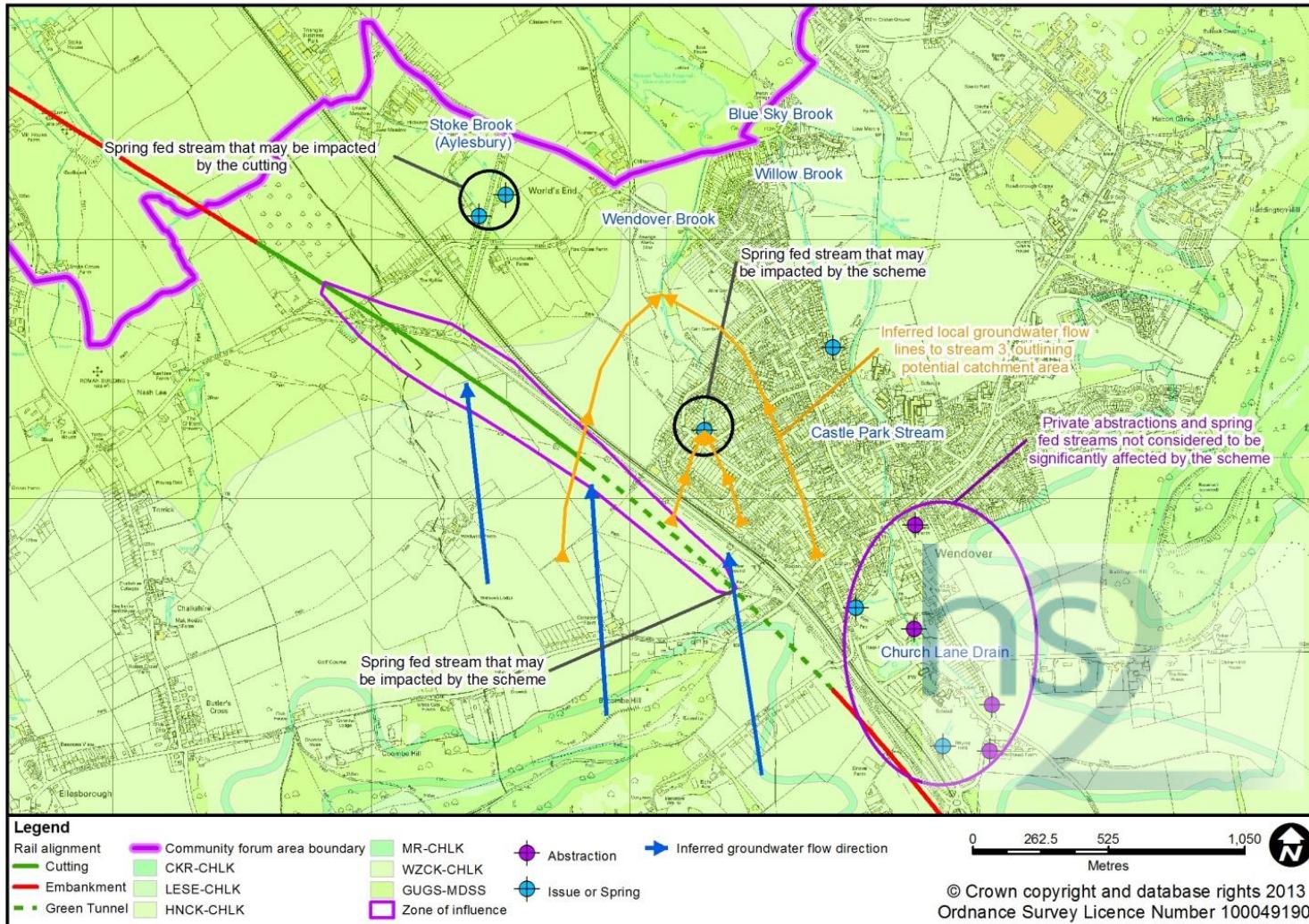
¹⁴ CIRIA, (1986), CIRIA C113: Control of groundwater for temporary works.

Figure 5: Schematic representation of dewatering, groundwater flows and zone of influence



- 5.2.12 Using Sichardt's formula the approximate maximum zone of influence has been determined to extend 122m from the route.
- 5.2.13 Figure 6 shows this zone relative to the route and the dominant groundwater flow direction which is towards the north-east. The maximum distance of influence is to the north-west of Wendover near the roundabout at the southern end of the A41.
- 5.2.14 Figure 6 also shows how the headwaters of the drain at Church Lane and the private licensed groundwater abstractions in southern Wendover are not affected by dewatering caused by the Proposed Scheme.

Figure 6: Schematic representation of zone of drawdown influence of wet cuttings at Wendover



Impacts on groundwater flows, springs and streams in the Wendover area

- 5.2.15 The following impacts have been assessed to occur at the five groundwater fed springs (see Figure 2) feeding local watercourses.
- 5.2.16 Spring 1 (drain at Church Lane) – no impact since the route will be above the water table in the catchment supplying the spring;
- 5.2.17 Spring 2 (Castle Park Stream and the Willow Brook) – there will be no impact since the route will be above the water table in the catchment supplying the spring;
- 5.2.18 Spring 3 (Wendover Brook) – there will be some flow reduction due to the Wendover north cutting and the Wendover green tunnel. The effect from the green tunnel will only be experienced during construction. Draining these features temporarily and permanently will intercept shallow groundwater flows but there will be less of impact in the permanent condition when the tunnel will be sealed as described below.
- 5.2.19 Figure 5 shows the probable groundwater catchments for the existing spring (Spring 3) and a point on the brook downstream. The figure shows that groundwater flow in about 50% of each catchment would be influenced by the Wendover green tunnel and Wendover North cutting. The cross section in Figure 3 shows that there will still be significant aquifer (Chalk and Upper Greensand) below the route, so the influence will not result in total interception as most groundwater will still flow below the excavated works (both during and after construction). Thus it is concluded the majority of flow will continue towards the Wendover Brook from the route. This proportion may drop in drought periods as groundwater elevations would naturally drop below the base of the Proposed Scheme (which conversely means that there will be no effect on the brook from the Proposed Scheme). Therefore there is predicted to be a negligible impact on groundwater flows to the Wendover Brook.
- 5.2.20 Springs 4 and 5 (Stoke Brook) - some flow reduction due to the interception of base flow to the headwaters will occur, particularly at the Stoke Brook source at World's End due to drawdown at the Wendover north cutting. Although all of the flow will be returned to the watercourse approximately 1km downstream of World's End, the reduction in the upstream 1km may be measurable. Should this occur, it would result in a localised minor impact with a moderate and therefore significant adverse effect. At the scale of the wider Stoke Brook, however, the effect is considered neutral.
- 5.2.21 Seasonal variations need to be accounted for when predicting impacts caused by disruption to groundwater flow. Generally the impact is determined to be negligible or minor. When groundwater levels are low (during periods of low rainfall or drought conditions) the disruption caused by the route will be negligible, as the water table is likely to be below or only marginally above the base of the route. During periods of high groundwater elevations, more groundwater will be intercepted by the route, but during periods of high groundwater elevations there will be a greater volume of water in the catchment and so any disruption caused will be minor in comparison to the overall groundwater flow regime within the system.

Impacts on Weston Turville Reservoir Site of Special Scientific Interest

- 5.2.22 Weston Turville Reservoir is classified as a SSSI notified under Section 28 of the Wildlife and Countryside Act 1981.
- 5.2.23 Although the bedrock geology of the majority of the study area comprises the Cretaceous Chalk Group, the Weston Turville reservoir site is on top of the Gault and Upper Greensand Formations. It therefore not likely to receive significant direct inflow through the base but relies on streams to supply the reservoir.
- 5.2.24 Weston Turville Reservoir was built to mitigate for the impact caused by spring flows in the Wendover being captured to fill the Grand Union Canal. The reservoir has several sources of supply including from the Grand Union Canal Wendover Arm. This is within 500m of the route and runs to the east and north of Weston Turville Reservoir. At times of high flow water from the Wendover Arm of the Grand Union Canal can be diverted down Willow Brook/Blue Sky Brook and into the reservoir for flood relief purposes (Canal & River Trust, personal communication, 2013).
- 5.2.25 A site inspection on the 10th May 2013 was undertaken to investigate the two potential key feeder streams; the Wendover Brook and Willow Brook. In addition, the Blue Sky Brook was also inspected. This visit confirmed the Wendover Brook does not routinely feed the reservoir - it can only contribute flow during high flow conditions. The Blue Sky Brook and Willow Brook are the main sources of flow into the reservoir. These are more than 1km from the route and will not be impacted by the Proposed Scheme.

Conclusion

- 5.2.26 In conclusion it is considered that there is no mechanism for the Proposed Scheme to intercept flows to the main groundwater fed streams that contribute flow to the Weston Turville Reservoir SSSI. As such, there will be a negligible impact and a neutral and not significant effect on the Weston Turville Reservoir SSSI.

Potential for groundwater quality impacts near Wendover

- 5.2.27 There are five private abstractions that will be within 1km to the north-east and down gradient of the route and therefore could be affected by the route. Details are summarised in Table 10 and shown on Map WR-02-010 (Volume 5: Water resources and flood risk assessment Map Book).

Table 10: Summary of private abstractions that near Wendover

Abstraction reference	Nearest design element	Distance from route (m)	Time of travel zone 1 intersected by route	Time of travel zone 2 intersected by route	Use of abstraction
GWA23d	Small Dean viaduct (piling)	625	No	No	Drinking, cooking, sanitary, washing, small garden
GWA24	Small Dean viaduct (piling)	287	No	No	General farming and domestic (agriculture)
GWA2	Small Dean viaduct (piling) Wendover green tunnel	405	No	Yes	Industrial, commercial, public services supply to canal for through-flow
GWA3	Wendover green tunnel	375	No	Yes	Industrial, commercial, public services supply to canal for through-flow
GWA20	Wendover green tunnel	660	No	No	General farming and domestic (agriculture)

- 5.2.28 Although the available groundwater elevation data suggest the water table will be below the route within the vicinity of these abstractions and thus have no potential to disrupt flow to the abstractions there is potential to affect groundwater quality, particularly if there are fast pathways through the unsaturated chalk to the water table.
- 5.2.29 The draft CoCP will ensure that fluids and potential contaminants used during construction will be stored and used in such a way as to ensure that there is a negligible impact on water quality. Notwithstanding this, the construction activity may lead to increased turbidity in the groundwater.
- 5.2.30 Two abstractions (GWA2 and GWA3) have a relatively large licenced abstraction and consequently the travel time zone 2 (i.e. 400 day travel time)¹⁵, as calculated using the Environment Agency methodology, will be crossed by the route as illustrated on Table 2.
- 5.2.31 The two abstractions (GWA2 and GWA3) whose quality could be affected are used for supply to the Grand Union Canal. As such, any slight increase in turbidity is not considered to adversely affect the overall quality of the canal water. Whilst the

¹⁵ For private licensed or unlicensed groundwater abstractions the time of travel zones indicate the extent of a 50day travel time (inner zone) and a 400day travel time (outer zone). The zones are defined as circles centred on the abstraction with the extent of the zone determined using the methodology applied to define PWS SPZ; Environment Agency(2013). Groundwater protection: Principles and practice (GP3). August 2013, version 1.1. For unlicensed abstractions, where the rate of abstraction will not exceed 20m³/d, the zones have been defined as a circle with radius 50m and 250m, for the inner and outer travel time zones, respectively.

groundwater abstractions are high value receptors, the impact is considered to be minor, resulting in a moderate but significant effect.

- 5.2.32 The three abstractions with travel time zone 2 that will not be crossed by the route (GWA20, GWA23d and GWA24) are not considered to be adversely affected by the scheme.
- 5.2.33 It is unlikely that further mitigation will be required at these five abstractions but a schedule of specific monitoring should be undertaken in consultation with the well owners to verify the quality of water is satisfactory for its use.

Balancing ponds/infiltration basins

- 5.2.34 A summary of the potential impact to groundwater quality underlying balancing ponds where they act as infiltration basins and fall within SPZ2 is presented in Table 11. The balancing ponds in the current design are presented in Maps CT-06-35 to CT-06-90 (Volume 2, CFA10 Map Book).
- 5.2.35 Detailed design of the infiltration basins will follow CIRIA C697 (2007)¹⁶ and CIRIA R156 (1996)¹⁷, which state that groundwater quality must not be impacted by infiltrating water in accordance with the requirements of the WFD and the Groundwater Protection; Policy and Practice (GP3) documentation (Environment Agency, 2012)¹⁸.
- 5.2.36 The drainage effluent will comprise land drainage that should not contain constituents that will significantly adversely affect the groundwater quality.

Table 11: Summary of effects to groundwater quality from drainage balancing/infiltration ponds

Location of balancing/infiltration pond and map reference	Approximate Chalk groundwater level (m AOD)	Approximate ground level (m AOD)	Unsaturated thickness (m)	Potential impact to groundwater quality
Will be north of Leather Lane. (CT-06-35, H5)	135	145 – 150	10 – 15	Will collect flows from ditch at toe of false cutting (South Heath cutting). Overlies SPZ1 for PWS TH3 ¹³ The pond overlies a moderate thickness (>10m) of unsaturated Chalk. With application of the CoCP and appropriate guidance documentation, as stated above, there will not be any constituents entering the groundwater that will adversely impact the overall groundwater quality.

¹⁶ Construction Industry Research and Information Association, CIRIA, (2007). C697; *The SuDS manual*. Reprinted in 2011 to incorporate errata since its publication in 2007. ISBN: 978-0-86017-697-8.

¹⁷ Construction Industry Research and Information Association, CIRIA, (1996), R156; *Infiltration drainage – Manual of good practice*. ISBN: 0 86017 457 3.

¹⁸ Environment Agency, (2013), *Groundwater protection: Principles and practice (GP3)*, GP3 version 1.1, August 2013.

Location of balancing/infiltration pond and map reference	Approximate Chalk groundwater level (m AOD)	Approximate ground level (m AOD)	Unsaturated thickness (m)	Potential impact to groundwater quality
Will be east of the A413 London Road. (CT-o6-37, H9)	132	150 – 155	18 – 23	Will receive track drainage from the western side of the South Heath cutting. Overlies SPZ2 for PWS TH313 As the basin overlies more than 15m unsaturated thickness of Chalk this will provide sufficient attenuation for constituents within the drainage water before drainage water enters the water table.
Two basins will be south and north of Bowood Lane and Wendover Dean Farm. (CT-o6-36, H7 and H9)	140	155 – 160 (north of Wendover Dean Farm) 175 (south of Wendover Dean Farm)	15 – 20 35	Will receive track drainage from the northern section of the South Heath cutting and highway drainage from the Bowood Lane crossing. Overlies SPZ2 for PWS TH313 As the basin overlies more than 15m unsaturated thickness of Chalk this will provide sufficient attenuation for constituents within the drainage water before drainage water enters the water table.
Three basins; two will be to the east of the route (north and south of Rocky Lane) and one to the west. (CT-o6-37, F8, F7, H7)	140	150 – 170	10 – 30	Will receive track drainage from the Small Dean south embankment and highway drainage from Rocky Lane. Does not overlie SPZ for PWS. As the basin overlies more than 10m unsaturated thickness of Chalk this will provide sufficient attenuation for constituents within the drainage water before drainage water enters the water table.
Small basin will be north of Bacombe Lane. (CT-o6-38, F6)	133	140 – 150	7 – 17	Will receiving track drainage from the Wendover green tunnel and highway drainage from Bacombe Lane and new road between Bacombe lane and Ellesborough Road. Does not overlie SPZ for PWS but is within outer travel time zone for GWA3 (only used to supply the Grand Union Canal). The basin overlies a moderate thickness of unsaturated Chalk, which will provide attenuation for constituents within the drainage water before drainage water enters the water table.

6 References

- British Geological Survey (BGS), (1978), *South West Chilterns Hydrogeological Map*. Product code HY07F, ISBN: 0751811823.
- British Geological Survey (BGS), (1997), *The aquifer properties of major aquifers in England and Wales*. Technical Report WD/97/34, Environment Agency R&D Publication 8.
- Centre for Ecology and Hydrology, (2009) *Flood Estimation Handbook (FEH)*, CD-Rom Version 3.0.
- Construction Industry Research and Information Association, CIRIA , (1996), *R156; Infiltration drainage – Manual of good practice*, ISBN: 0 86017 457 3.
- Construction Industry Research and Information Association, CIRIA, (2007), *C697; The SuDS manual*. Reprinted in 2011 to incorporate errata since its publication in 2007. ISBN: 978-0-086017-697-8.
- Construction Industry Research and Information Association , CIRIA, (1986), *CIRIA C113: Control of groundwater for temporary works*.
- Construction Industry Research and Information Association , CIRIA, (2000), *CIRIA C515: Groundwater control – design and practice*.
- Environment Agency, (2009), *River Basin Management Plan*, Thames River Basin District.
- Environment Agency, (2013), Groundwater protection: Principles and practice (GP3). GP3 version 1.1, August 2013.
- Water Framework Directive - *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy*, Strasbourg, European Parliament and European Council.
- Wildlife and Countryside Act*, (1981), London, Her Majesty's Stationery Office.